



DEVELOPMENTS IN  
PETROLEUM SCIENCE

61

# STRATIGRAPHIC RESERVOIR CHARACTERIZATION FOR PETROLEUM GEOLOGISTS, GEOPHYSICISTS, AND ENGINEERS

ORIGIN, RECOGNITION, INITIATION, AND RESERVOIR QUALITY

SECOND EDITION

ROGER M. SLATT

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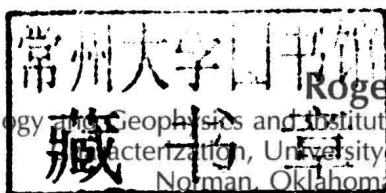
Developments in Petroleum Science

Volume 61

# Stratigraphic Reservoir Characterization for Petroleum Geologists, Geophysicists, and Engineers

Origin, Recognition, Initiation, and  
Reservoir Quality

Second Edition



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Developments in Petroleum Science

Volume 61

**Stratigraphic Reservoir  
Characterization for Petroleum  
Geologists, Geophysicists, and  
Engineers**

Origin, Recognition, Initiation, and Reservoir Quality

Second Edition



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## Dedication

This book is dedicated to my loving wife of 26 years—Linda Gay Slatt (1944–2013)—who was, and always will be, my source of inspiration, courage, motivation, encouragement, and guidance. She touched and brightened the lives of many with her grace, wisdom, generosity, and kindness.



Much has changed in the field of reservoir characterization, as well as in the world, since the first edition of this book was published in 2006. Technological advances, coupled with new directions in exploration and development of hydrocarbons, increasing global energy demand and new energy sources and energy-related issues, prompted this updated second edition. In addition to replacing some of the older case histories and other aspects of the first edition, two new chapters have been added to this second edition.

The first addition is on shales (i.e., “mudrocks”) as an unconventional resource (Chapter 12). Not many would have believed in 2006 that the most abundant rock type in the stratigraphic record would be capable of producing vast quantities of gas and oil, enough to make countries energy independent, and net exporters instead of importers of hydrocarbon fuels. The second addition is on the basics of geological and engineering modeling (Chapter 13). A chapter on this subject was not included in the first edition because the field was expanding too rapidly. The pace of advancement in modeling concepts, programs, and applications has not really diminished since 2006, so it was decided to include this chapter (mainly written by Dr. Fuge Zou) as background material for someone just needing to know the modeling basics.

I have been very fortunate in having experienced a dual career spanning 14 years in the petroleum industry and 29 years in academia. Thus, this book carries with it my experience in the scientific and technical aspects of reservoir characterization as well as my understanding of the necessity for explaining a concept or practice in a manner that is understandable to technical people from a variety of experience levels and interests. To accomplish this, I have drawn upon personal experiences in reservoir characterization and also upon both classic and recently published comprehensive literature, including graduate student theses and dissertations. The course from which this book evolved is actually a flexible series of topics presented to graduate-level students, to domestic and international petroleum companies, to petroleum societies and organizations, and formerly as a public, online Web (distance-learning) course.

Reservoir characterization as a discipline grew out of the recognition that more oil and gas could be extracted from reservoirs if the geology of the reservoir was understood. Prior to that awakening, reservoir development and production were the realm of the petroleum engineer. In fact, geologists of that time would have felt slighted if asked by corporate management to move



from an exciting exploration assignment to a more mundane assignment working with an engineer to improve a reservoir's performance.

Slowly, reservoir characterization came into its own as a quantitative, multidisciplinary endeavor requiring a vast array of skills and knowledge sets. Perhaps, the biggest attractor to becoming a reservoir geologist was the advent of fast computing, followed by visualization programs and theaters, all of which allow young geoscientists to practice their computing skills in a highly technical, rewarding work environment. Also, the discipline grew in parallel with the evolution of data integration and the advent of asset teams in the petroleum industry. With the ever-increasing global demand for energy, partly alleviated by extracting more hydrocarbons from existing or young fields, the science of reservoir characterization is now flourishing. Quantum improvements in geophysical acquisition and processing techniques allow geophysicists to image internal reservoir complexities, quantitative geological reservoir models can now be based on extensive outcrop and mature field studies, and the computing capabilities are in place to relatively quickly build computer-simulation models of reservoirs for performance prediction and volumetric calculations.

As was the case in 2006, universities still lag behind this discipline's growth in the petroleum industry. With the exception of some geosciences departments in U.S., European, and Australian universities, young geoscience students typically do not get much opportunity to interact and study with their engineering counterparts. Students at those universities now are reaping the benefits of relatively steady industry recruitment that aims to avoid the demographic trap of workers collectively approaching retirement age at a time when energy demand is increasing globally.

Thus, this book is intended as a primer for geologists and geophysicists whose education and careers have taken them to this fascinating, multifaceted discipline. The book is also for petroleum engineers who seek to understand what geologists and geophysicists do and to explore how all three groups can help improve reservoir performance in a team setting.

The book focuses on stratigraphic aspects of characterization, with particular emphasis on understanding the primary control that depositional processes and systems exert on reservoir performance, and the extent (or sometimes the limits) to which stratigraphic features can be predicted away from the wellbore. Unlike the first edition, this second edition is built around a sequence stratigraphic framework since that discipline has matured to a point of common usage in subsurface prediction of the occurrence of source, seal, and reservoir rocks of all types and in most places.

I have purposefully avoided much discussion of structural aspects of reservoirs because it is a vast field in itself. For the same reason, I apply engineering principles in only a peripheral manner.

Yes, the discipline of reservoir characterization is complex, comprehensive, multidisciplinary, and exciting. It promises many careers for young

people entering the petroleum industry and for more experienced individuals seeking to broaden their horizons.

I would like to acknowledge individuals with whom I have had the honor and pleasure to work with, and learn from, during my years in petroleum geoscience. These people include, but are not limited to, Hamid Al-Hakeem, Al Barnes, Greg Browne, Mike Burnett, Dave Campbell, John Castagna, Bob Davis, Marlan Downey, Jim Ebanks Jr., Eric Eslinger, Camilo Goyeneche, Neil Hurley, Cretis Jenkins, Doug Jordan, John Kaldi, T.K. Kan, Marcus Milling, Shankar Mitra, Clyde Moore, Matthew Pranter, Dave Pyles, Bill Reed, Mark Scheihing, Bob Sneider, Charles Stone, Rod Tillman, Lew and Myra Ward, John Warme, Bob and Paul Weimer, Jon Withrow, Alan Witten, and Fuge Zou. I also thank the 70+ graduate students that I have so far had the pleasure to work with and graduate while at OU. The patience and encouragement of my late-wife Linda Gay during the writing of this book is also greatly acknowledged. My son Andrew Slatt, and Ms. Lingxin (Cindy) Meng completed most of the excellent graphics used in the book and Carol Drayton spent many long and sometimes frustrating hours editing chapters and securing permissions to publish figures. My other son Tom Slatt frequently provided food for thought and nourishment at his restaurant. Finally, I am especially indebted to Robert Stephenson for providing the incentive for me to take up residence at the University of Oklahoma in 2000 to enhance its energy program, and for providing continued financial support that has allowed me to complete both the first and second editions of this book.

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## Series Editor's Preface

In the latest book published in this series, *Geophysics for Petroleum Engineers*, written by Professor F. Aminzadeh and Dr. S.N. Dasgupta, I had the pleasure of providing a brief preface that emphasized the strong need to maintain and improve lines of communication among and between modern reservoir, drilling, and production engineers and geophysicists, geologists, and petrophysicists. That volume, produced by experts in the geosciences and engineering within industry and academia, was designed and written with alleviating the traditional communication gap between the disciplines and asset team members firmly in mind.

Now in the second edition of Professor Roger Slatt's popular book on *Stratigraphic Reservoir Characterization for Petroleum Geologists, Geophysicists, and Engineers*, we have the ability to build on that important message. He realized that reservoir characterization as a discipline grew out of the recognition that more oil and gas could be extracted from reservoirs if the detailed geology of those reservoirs was better understood by both geoscientists and engineers. Over the past 30 years, it has developed into a multidisciplinary technical activity employing the very latest in computer, data management, and visualization technologies. In the new business world of asset teams, the use of reservoir characterization leapt forward when 3D and 4D geophysical acquisition and processing allowed geoscientists and engineers to image and model reservoir complexities and even the flow of hydrocarbons through reservoirs.

Professor Slatt has in the light of numerous technical advances in reservoir characterization over the past 10 years put together a book that emphasizes stratigraphic aspects of reservoir characterization in particular the role depositional processes and environments have on reservoir performance and the prediction of stratigraphic features away from the well bore. This edition also has an enlarged section on modern sequence stratigraphy and its role in improving our understanding of reservoir intricacies and the resulting impact on production of hydrocarbons.

Nowhere is there greater demand for this understanding than in the vitally important and rapidly growing world of unconventional reservoirs including gas and oil shales, tight gas sandstones, and coal-bed methane. So a new chapter on this topic has been added to this edition.

In the preface to the first edition of his book, Professor Slatt stated that "this book is intended as a primer for geologists and geophysicists whose education and careers have taken them into this fascinating, multifaceted

discipline. The book is also for petroleum engineers who seek to understand what geologists and geophysicists do and to explore how all three groups can help reservoir performance in a team setting." These important intentions apply as much to this edition and will help to improve communication between these three technical areas.

This preface also provides an opportunity to remind readers that the *Developments in Petroleum Science* series will now incorporate the *Handbook of Petroleum Exploration and Production* series going forward. As currently Series Editor of the *Handbook of Petroleum Exploration and Production*, I will continue as Series Editor of the *Developments in Petroleum Science* series and hope that readers will enjoy the combined series.

John Cubitt  
Holt, Wales

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